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Development of multi millet based extruded snack food

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Abstract
Ready-to-eat snack products using extrusion technology were prepared with multi millet based composite formulations. Sorghum fine semolina, finger millet fine semolina, Foxtail millet Fine semolina, Pear millet fine semolina, corn, Bengal gram flour and rice flour blends in various proportions were studied. Pre-conditioning was done to prepare the flours for extrusion cooking and moisture content was adjusted for 21-23% for all the formulations. Extrusion cooking was carried out using a twin screw extruder at optimized extrusion parameters viz., temperature: 110˚C and 140°C for two different heating zones, die diameter: 2 mm, screw speed: 26 hz and cutter speed: 8 hz and feeder speed is 13hz. Physical properties of the extrudate viz., mass flow rate, bulk density, tap density, expansion ratio, moisture retention and nutrient analysis along with storage stability with two different packaging of the products were also analyzed. The organoleptic qualities of extruded samples were analyzed by panellists on a 7 point hedonic scale. The results indicated that composite flour (flours in the ratios of 12.5:12.5:12.5:12.5:35:8:7) could be used to produce quality extrudates with acceptable sensory properties.

Keywords: Sorghum, finger millet, foxtail millet, pearl millet, composite flour, extrusion cooking and preconditioning

1. Introduction

Extrusion cooking with composite flour is a novel technique to prepare nutritional enriched food products. Extrusion cooking process is a high temperature short time process in which moist, soft grain is fed into the extruder where the desired temperature and pressure are obtained over the required period of residence time. For cooking of the product generally external heat is not supplied, heat for cooking is achieved through shear and friction in the extruder. Extrusion cooking is used worldwide for the production of expanded snack foods, modified starches ready-to- eat cereals, baby foods, pasta and pet foods. (Toft, 1979) [3]. This technology has many distinct advantages like versatility, low cost, better product quality and no process effluents (Abbott 1987; Camire *et al*., 1990) [4,]. Snacks contribute an important part of daily nutrient and calorie intake for many consumers. Cereals have been popular raw materials for extrusion for food uses mainly because of functional properties, low cost and ready availability. Owing to high protein content, pulses and oilseeds can be effectively utilized for nutritional improvement of cereal based extruded snack foods.

Sorghum (*Sorghum bicolour*) moisture ranged 8.7-10.3%and has protein, fat, ash, crude fiber and carbohydrates of 10.4, 1.9, 1.78, 1.6 and 72.6 g/100g respectively. It gives energy ranging between 202.6 to225.6 Kcal and is rich in calcium (25 mg/100g) and phosphorous (0.46 mg/100g). Finger millet (*Setaria italica*) ranks second in the total world production of millets. It contains 9–14% protein, 70–80% carbohydrates and is a rich source of dietary fiber (Hadimani and Malleshi, 1993) [9]. It contains maximum amount of chromium among all the millets with an account of 0.030 mg per 100 g. Polymers of hexose's, pentoses, cellulose and pectinacious material constitute the major portion of its dietary fibre (Malleshi,1986) [8]. Millet is a starchy food with a 25:75 amylose to amylopectin ratio and is a fairly good source of lipids (3–6%), having about 50% of the lipids in the form of poly-unsaturated fattyacids (Sridhar and Lakshminarayana, 1994) [10]. Foxtail millet (*Setaria italica*) contains 9–14% protein, 70–80% carbohydrates and is a rich source of dietary fiber (Hadimani and Malleshi, 1993) [9]. It contains maximum amount of chromium among all the millets with an account of 0.030 mg per 100 g. Polymers of hexose's, pentoses, cellulose and pectinacious material constitute the major portion of its dietary fiber (Malleshi, 1986) [8].

Millet is a starchy food with 25:75 amylose to amylopectin ratio and is a fairly good source of lipids (3–6%), having about 50% of the lipids in the form of polyunsaturated fatty acids (Sridhar and Lakshminarayana, 1994) [10]. Although millet is known to contain amylase inhibitors, the carbohydrate digestibility of millet foods is not affected because of heat-labile nature of the inhibitors (Chandrasekher *et al*., 1981) [11]. Even though the nutritional qualities of millet have been well recorded (Hulse*et al*., 1980), its utilization for food is confined to the traditional consumers in tribal populations, mainly due to non-availability of consumer friendly, ready-to-use or ready-to-eat products as are found for rice and wheat. In recent years, millets have received attention, mainly because of their high fiber content and efforts are under way to provide it to consumers in convenient forms.

2. Materials and Methods

Sorghum, Pearl millet, Finger millet, Foxtail millet, Corn, Bengal gram flour and Rice flours were ground separately and passed through a 2.5mm screen.

A. Composite flour preparation

Blends were prepared by mixing sorghum, Pearl millet, Finger millet, Foxtail millet, Corn, Bengal gram flour and Rice in the different ratios on a dry-to-dry weight basis. These blends were chosen according to preliminary tests without jamming of extruder and for acceptable product's physical characteristics as well as better nutritive value in the final product. The chosen blend was sorghum, millet, Finger millet, foxtail millet, Corn, Bengal gram flour and Rice in the ratios of 12.5:12.5:12.5:12.5:35:8:5. The blended samples were conditioned to 20–21% (w.b) moisture by spraying with a calculated amount of water and mixing continuously. Moisture content of samples was determined by hot air oven method (AOAC 1990) [9].

B. Extrusion Cooking

Feeding of the pre conditioned composite flour to a twin screw extruder was accomplished by using a twin screw volumetric gravity feeder. Based on the most stable product expansion and stability of the extruder conditions, the extrusion conditions were used (Deshpande *et al*., 2011) [7]. The temperature of the two barrel zones of extruder from feeder end were set at 90oC and 140oC respectively. Samples were collected at the most stable die temperature which was around130oC. Screw speed was set up at 26 hz and equipped with2-mm restriction die to extruder. Constant feeding rate was kept throughout the experiments. Three replicate samples were extruded and dried to about 5% moisture level. The dried samples were mixed with spices and edible oil.

Table 1: Standardization of formulation of composite flours

Ingredients	Composite Flour Samples		
	T1	T2	T3
Sorghum semolina	12.5	12.5	12.5
Pearl millet semolina	12.5	12.5	12.5
Finger millet semolina	12.5	12.5	12.5
Foxtail millet semolina	12.5	12.5	12.5
Corn semolina	35	0	15
Corn flour	0	35	20
Bengal gram flour	6	8	8
Rice flour	7	5	5
Salt	2	2	2

C. Product analysis

Expansion ratio

The ratio of diameterof extrudate and the diameter of die was used to express the expansion of extrudate (Fan *et al*., 1996) [6]. The diameter of extrudate was determined as the mean of 10 random measurements made with a Vernier caliper. The extrudate expansion ratio was calculated as

$$\text{Expansion ratio} = \frac{\text{Extrudate Diamete}}{\text{Die Diameter}}$$

Bulk density

Bulk density (BD) was measured by measuring the actual dimensions of the extrudates and calculated as ratio of weight of product to its volume (Asare *et al*. 2004).

$$\text{Bulk density} = \frac{4 \times m}{\pi \times d^2 \times l}$$

Where,
L =Length of extrudate (cm)
d =Diameter of extrudate (cm)
m=Mass of sample (g)

Water Absorption Index (WAI) and Water Solubility Index (WSI)

WAI and WSI were determined by the method of Anderson (1982a) [5]. The extruded puffs were milled to a mean particle size of 200–250 μm. A 2.5 g sample was dispersed in 25 g distilled water, using a glass rod to break up any lumps and then stirred for 30 min. The dispersions were rinsed into tarred centrifuge tubes, made up to 32.5 gms and then centrifuged at 4000 rpm for 15 min. The supernatant was decanted for determination of its solid content and sediment was weighed. WAI and WSI were calculated as,

$$\text{WAI} = \frac{\text{Weight of Sediment}}{\text{Weight of Dry Solids}}$$

$$\text{WSI} = \frac{\textit{Weight of Dissolved in Supernatant}}{\textit{Weight of Dry solids}}$$

Estimation of moisture content

Moisture content of the samples was determined by using hot air oven method for every 15 days. A sample of 5gm was accurately measured into a clean and dry moisture boxes of known weight and dried in a hot air oven at 105^{0}C for 12-15 hrs, cooled in a desiccators and weighed (AOAC,1990) [9].

$$\text{Moisture content} = \frac{\text{Initial weight – final weight}}{\text{Sample weight}} \times 100$$

Estimation of Protein Content by Micro Kjeldahl Method (AOAC, 1990) [9]

Reagents

The reagents required for digestion, distillation and titration are given below respectively.

Digestion

1. 98% pure concentrated Sulphuric acid 10ml per sample.
2. Catalyst mixture or digestion mixture or activator (5:1) for each tube. Potassium sulphate (100gm) and copper
3. sulphate (20gm).

Distillation

1. 40% NaOH (400gm of NaOH in 1liter of distilled water)-40ml per sample.

2. 4%Boric acid: 40gm in lit of distilled water-25ml/sample.
3. Mixed indicator: 2parts of methyl red indicator, 1 part of Bromocresol green.

Titration

1. 0.1N HCl or $H_2 S0_4$

Calculations

The percentage of nitrogen present in the given sample

$$= \frac{(\text{sample titre value} - \text{blank titre}) \times \text{No of acid} \times 14 \times 100}{Sample\ weight \times 1000}$$

The percentage of protein present in the given sample = % N × 6.25 factor

Sensory Evaluation

The sensory assessments were conducted at Indian Institute of Millets Research COE laboratory. The panel of 20members consisted of staff and project trainee students of the College of Food Technology, Bapatla and Central University of Agricultural Dehradun. The panelists were naive to project objectives. Samples (T_1, T_2 &T_3) flavored with Magic masala spice powder was used in the evaluation. Samples were coded randomly and served with the order of presentation counter-balanced. Panelists were provided with a glass of water and instructed to rinse and swallow water after testing every sample. Panelists are evaluated all samples based on its the based for acceptability based on its flavor, texture, taste, color and overall acceptability using seven-point hedonic scale (1 = dislike very much to 7 = like very much; Meilgaard *et al*., 1999).

3. Results and Discussion

Bulk Density

The bulk density of extrudates samples T1 and T2 were almost same but in case of sample- T3 (0.09±0.06), the higher bulk density may be due to the presence of more crude fibre in the composite flour sample. Similar types of results were observed by Singh *et al*. (1996) [12].

Water Solubility Index

Water solubility index (WSI) was more for the extrudates made from composite flour sample –T2 (0.39±0.04) followed by extruded sample –T3 (0.37±0.07) and WSI was less for the extrudates prepared from composite flour sample-T1 (0.29±0.02). The water solubility index of the extrudates increased when bengal gram flour incorporation increased in the composite flour samples. The water absorption index was found to be more for extruded sample –T1 (5.6±0.04) followed by extruded sample –T2 (5.4±0.07) and sample –T3 (5.2±0.06). These results are inconformity with the observations made by Shirani and Ganeshranee (2009).

Expansion Ratio

The result of expansion ratio of extrudates indicates that expansion ratio decreased with increased level of cereals starch and decreased amount of proteins in the composite flour–T1 (4.23±0.01). This decrease in expansion ratio could be because of high level of millet flour, which is rich in dietary fiber. Protein affects expansion through their ability to effect water distribution in the matrix and through their macromolecular structure and confirmation. The extruded sample –T2 (4.46±0.05) has more expansion ratio than extruded sample–T3 (4.34±0.03) and extruded sample-T1. Similar findings were reported by Singh *et al.* (1996) [12].

Hardness

Hardness Textural quality of the extruded snacks was examined by using a TA-CT3 Texture Analyzer (Brookfield Engineering Labs. Inc.). The compression probe (TA4/100; D) was applied to measure the compression force required for samples breakage which indicates hardness. Hardness of extruded snacks was expressed in Newton (1N = 101.97 g force). Testing conditions were 2.0 mm/s pre-test speed, 2.0 mm/s test speed, 10.0 mm/s posttest speed and 5 mm distance. The hardness of finger millet based extrudates was determined by measuring the force required to break the extrudates. The higher the value of maximum peak force required in gram, which means the more force required to breakdown the sample, the higher the hardness of the sample to fracture. Hardness of finger millet based extrudates varied between 60.97 and 62.89 N. As is shown in Table 2 increasing multi millet flour level resulted in increase in peak force of extrudates. Fig 1 shows that T3 having decreased hardness compared to T1&T2.

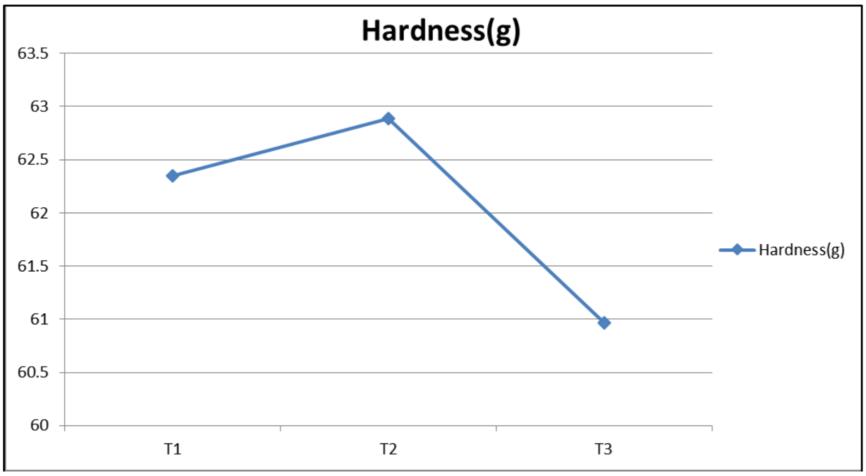

Fig 1: Hardness of the extrudetes

Table 2: Physical properties of extrudates

Physico Chemical Properties	Composite Flour Samples		
	T1	**T2**	**T3**
Bulk density(Kg/cm3)	0.12±0.03	0.11±0.06	0.09±0.09
Water Solubility Index (%)	0.29±0.02	0.39±0.04	0.37±0.07
Water Holding Capacity (WHC)	302±0.01	320±0.02	319±0.07
Moisture Retention	3.7±0.02	3.54±0.06	3.05±0.02
Expansion Ratio	4.23±0.01	4.46±0.05	4.34±0.03
Water Absorption Index (%)	5.6±0.04	5.4±0.07	5.2±0.06
Hardness(N)	62.35±2.19	62.89±1.68	60.97±2.87

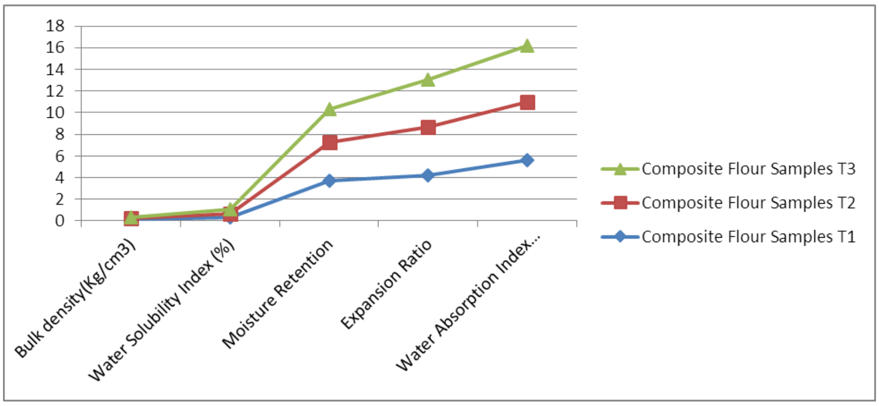

Fig 2: Physical properties of the extrudetes

Sensory attributes

The sensory assessments were conducted with the panel of 20members consisted of staff and project trainee students of the College of Food Technology, Bapatla and Central University of Agricultural Dehradun. The panel members were given the extruded snack food samples for evaluation of organoleptic characteristics viz. appearance, colour, taste, flavour, texture and overall acceptability. It was served to judges on the day of preparation. The average score recorded by judges was considered. The mean scores of sensory evaluation showed that all the extruded products prepared from composite flours were within the acceptable range, while the extruded product prepared from composite flour sample-T3 had better appearance (6.00±0.01), color (5.31±0.01), flavor there is no significant variations in the samples (5.13±0.02), texture (5.92±0.05), taste (5.77±0.04) and overall acceptability (5.69±0.03) when all the prepared extruded samples were compared with the commercial control.

Table 3: Mean sensory score values for the extruded snack food

Sensory attributes	Extruded Sample		
	T1	**T2**	**T3**
Colour	5.10±0.02	5.46±0.02	5.31±0.01
Flavour	5.09±0.01	5.10±0.04	5.13±0.02
Texture	4.90±0.03	5.15±0.03	5.92±0.05
Taste	4.50±0.05	5.31±0.01	5.77±0.04
appearance	4.10±0.02	4.69±0.03	6.00±0.01
Overall	5.30±0.04	5.15±0.04	5.69±0.03

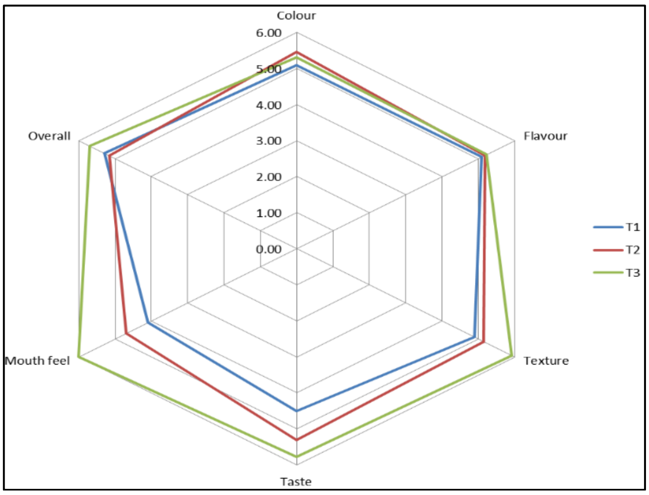

Fig: 3 Sensory attributes of the extrudetes

Conclusion

The present study revealed that composite flour (Sorghum fine semolina, finger millet fine semolina, Foxtail millet Fine semolina, Pear millet fine semolina, corn, Bengal gram flour and rice flour) in the ratios of (12.5:12.5:12.5:12.5:35:8:7) best suits to produce desirable qualities of the extrudates such as high expansion ratio, low bulk density, low hardness, and low moisture content with acceptable sensory properties.

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